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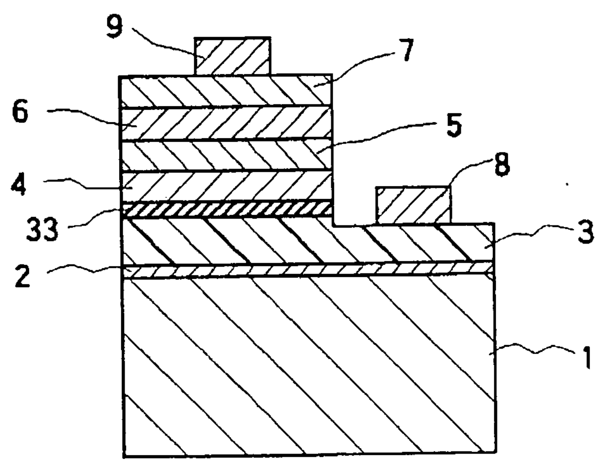
(54)【発明の名称】窒化ガリウム系化合物半導体発光素子

(57)【要約】
【目的】　活性層より均一な発光を得て、素子の光度、出力を向上させ、また発光素子のVfをさらに低下させて、発光効率を向上させる。
【構成】　少なくともn型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、前記n型層は基板側に形成された第一のn型層3と、その第一のn型層3に接して活性層5側に形成されて、第一のn型層3よりも電子キャリア濃度が大きい第二のn型層33とを含む。



【特許請求の範囲】

【請求項１】　少なくともｎ型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、前記ｎ型層は基板側に形成された第一のｎ型層と、その第一のｎ型層に接して活性層側に形成されて、第一のｎ型層よりも電子キャリア濃度が大きい第二のｎ型層とを含むことを特徴とする窒化ガリウム系化合物半導体発光素子。

【請求項２】　前記第二のｎ型層が少なくともインジウムを含む窒化ガリウム系化合物半導体（$In_XAl_YGa_{1-X-Y}N$、$0<X$、$0\leqq Y$、$X+Y\leqq 1$）よりなることを特徴とする請求項１に記載の窒化ガリウム系化合物半導体発光素子。

【請求項３】　前記第二のｎ型層は互いに組成の異なる窒化ガリウム系化合物半導体層が２層以上積層された多層膜よりなることを特徴とする請求項１または請求項２に記載の窒化ガリウム系化合物半導体発光素子。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明はレーザダイオード（ＬＤ）、発光ダイオード（ＬＥＤ）等の発光素子に使用される窒化ガリウム系化合物半導体（$In_aAl_bGa_{1-a-b}N$、$0\leqq a$、$0\leqq b$、$a+b\leqq 1$）よりなる発光素子に関する。

【０００２】

【従来の技術】現在、実用化されている光度１ｃｄの青色ＬＥＤは窒化ガリウム系化合物半導体（$In_aAl_bGa_{1-a-b}N$、$0\leqq a$、$0\leqq b$、$a+b\leqq 1$）よりなり、図１に示す構造を有している。それは、サファイアよりなる基板１の表面に、ＧａＮよりなるバッファ層２と、ＧａＮよりなるｎ型層３と、ＡｌＧａＮよりなるｎ型クラッド層４と、ＩｎＧａＮよりなる活性層５と、ＡｌＧａＮよりなるｐ型クラッド層６と、ＧａＮよりなるｐ型コンタクト層７とが順に積層されたダブルヘテロ構造である。この青色ＬＥＤは順方向電流（Ｉｆ）２０ｍＡにおいて、順方向電圧（Ｖｆ）３．６Ｖ、ピーク発光波長４５０ｎｍ、光度１ｃｄ、発光出力１．２ｍＷと、青色ＬＥＤでは過去最高の性能を示している。

【０００３】前記構造のＬＥＤにおいて、基板１はサファイアの他にＺｎＯ、ＳｉＣ、ＧａＡｓ、Ｓｉ等の材料が使用可能であるが、一般的にはサファイアが用いられる。バッファ層２はＧａＮの他、ＧａＡｌＮ、ＡｌＮ等が形成される。ｎ型コンタクト層３、ｎ型クラッド層４は窒化ガリウム系化合物半導体にＳｉ、Ｇｅ、Ｓｎ、Ｃ等のｎ型ドーパントをドープした窒化ガリウム系化合物半導体で形成される。また、ｎ型コンタクト層３、ｎ型クラッド層４は、このように二層に分けなくても単一のｎ型層として、クラッド層およびコンタクト層として作用させてもよい（つまり、いずれかの層を省略できる）。活性層５は少なくともインジウムを含む窒化ガリウム系化合物半導体よりなり、ノンドープ、Ｚｎ、Ｍｇ、Ｃｄ、Ｂｅ等のｐ型ドーパント及び／またはｎ型ドーパントがドープされている。ｐ型クラッド層６、ｐ型コンタクト層７は窒化ガリウム系化合物半導体にｐ型ドーパントをドープした後、４００℃以上でアニーリングすることにより、ｐ型とされている。また、ｐ型クラッド層６、ｐ型コンタクト層７は、単一のｐ型層として、クラッド層およびコンタクト層として作用させてもよい（ｎ層と同様にいずれかの層を省略可能）。

【０００４】

【発明が解決しようとする課題】窒化ガリウム系化合物半導体の場合、他のＧａＡｓ、ＧａＰ、ＡｌＩｎＧａＰ等のIII－Ｖ族化合物半導体に比べて、一般に電流が均一に広がりにくいという性質を有している。そこで図１のような構造のＬＥＤ素子を実現した場合、ｎ層から活性層に供給される電子の流れが、抵抗の低い箇所に集中してしまうという問題がある。図２は電流の集中による活性層の発光を模式的に示している。これは、ｎ型コンタクト層３の負電極８より供給された電子が、図２の矢印に示すように、ｐ型コンタクト層７の正電極９と、ｎ型コンタクト層３の負電極８との間の抵抗が低くなるように、いちばん近い距離を流れることにより、活性層５が網掛け部で示すように部分的に強く発光していることを表している。このように、電子がｎ型コンタクト層３に均一に広がらないと、活性層５から均一な発光が得られないという欠点がある。

【０００５】また、上記構造のＬＥＤはＶｆ３．６Ｖと、従来のＭＩＳ構造の窒化ガリウム系化合物半導体よりなる青色ＬＥＤに比べて、５Ｖ以上Ｖｆを低下させた。これはｐ－ｎ接合による発光を示すものであるが、Ｖｆについてもまだ改良する余地があり、さらなるＶｆの低下が望まれている。

【０００６】従って本発明はこのような事情を鑑みてなされてものであり、その目的とするところは、ダブルヘテロ、シングルヘテロ等、少なくともｎ型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、まず第一に活性層より均一な発光を得て、素子の光度、出力を向上させることにあり、第二にＶｆをさらに低下させて、発光効率を向上させることにある。

【０００７】

【課題を解決するための手段】我々はｎ型層にさらにキャリア濃度の高い層を介在させることにより、上記問題が解決できることを見いだした。即ち、本発明の窒化ガリウム系化合物半導体発光素子は、少なくともｎ型層が活性層と基板との間に形成された構造を備える窒化ガリウム系化合物半導体発光素子において、前記ｎ型層は基板側に形成された第一のｎ型層と、その第一のｎ型層に接して活性層側に形成されて、第一のｎ型層よりも電子キャリア濃度が大きい第二のｎ型層とを含むことを特徴

とする。

【０００８】本発明の一実施例の発光素子の構造を図３に示す。基本的な構造は図１に示す発光素子とほぼ同じであるが、第一のｎ型層であるｎ型コンタクト層３に接して、活性層５側にその第一のｎ型層３よりも電子キャリア濃度が大きい新たな第二のｎ型層３３を形成している。基板１、バッファ層２、ｎ型コンタクト層３、ｎ型クラッド層４、活性層５、ｐ型クラッド層６、ｐ型コンタクト層７等は窒化ガリウム系化合物半導体で形成され、ｎ型コンタクト層３とｎ型クラッド層４とを単一のｎ型層とすることもでき、またｐ型クラッド層６とｐ型コンタクト層７とを単一のｐ型層とすることもできる。

【０００９】本発明の発光素子において、結晶性に優れた窒化ガリウム系化合物半導体層を成長させるには、基板１にサファイアを好ましく用い、バッファ層２にＧａＮ、またはＡｌＮを成長させ、１０オングストローム～０．５μｍの膜厚で形成することが好ましい。

【００１０】活性層５と基板１との間に形成する第一のｎ型層は、ｎ型コンタクト層３としては通常１μｍ～５μｍの膜厚で形成し、その表面にｎ型クラッド層４を形成する場合には５０オングストローム～１μｍの膜厚で成長する。但し、前記のように、このｎ型クラッド層４は特に形成しなくてもよい。窒化ガリウム系化合物半導体としてはＧａＮ、ＡｌＧａＮが好ましく、最も好ましくはＧａＮとする。なぜならＧａＮ、ＡｌＧａＮはノンドープあるいはｎ型ドーパントをドープして容易にｎ型となり、ドーパントにより電子キャリア濃度を制御することが容易である。さらにＡｌＧａＮよりも単一層で結晶性のよい厚膜を形成するにはＧａＮが成長しやすい。例えば、サファイアを基板としてｎ型層とｐ型層とを順に積層した素子を実現した場合、ｎ型コンタクト層３の電極８を設けるため、ｐ型層をエッチングにより取り除き、ｎ型コンタクト層３を露出させる必要があるが、単一層で厚膜が形成できると、エッチング深さの遊度があるので、実際の素子を実現する際に非常に好都合である。

【００１１】次に、活性層５は、通常５０オングストローム～０．５μｍの膜厚で成長し、ＩｎＧａＮとすることが好ましい。ＩｎＧａＮはインジウムの混晶比によりバンド間発光を利用して発光素子の発光波長を紫～緑色まで容易に変化させることができ、さらにｎ型、ｐ型のドーパントをドープして発光中心とすることも容易である。さらにＩｎのＧａに対する混晶比（Ｉｎ／Ｇａ）は０．５以下であることが好ましい。０．５より多いＩｎＧａＮは結晶性がよくないので実用的な発光素子を得ることが困難となる傾向にある。最も優れた活性層としてはｎ型ドーパントと、ｐ型ドーパントとがドープされてｎ型とされ、Ｇａに対するＩｎ混晶比が０．５以下のＩｎＧａＮを活性層とすることが好ましい。

【００１２】活性層５の上に成長するｐ型層もＧａＮ、

ＡｌＧａＮが好ましく、ｐ型クラッド層６は５０オングストローム～１μｍの膜厚で形成し、ｐコンタクト層７は５０オングストローム～５μｍの膜厚で成長する。但し、このｐ型クラッド層６は特に形成させなくてもよい。窒化ガリウム系化合物半導体としてはＧａＮ、ＡｌＧａＮを好ましく形成する、これらは単一層で結晶性のよい厚膜が成長しやすく、またｐ型ドーパントをドープして４００℃以上でアニールすると容易にｐ型となる傾向にある。

【００１３】

【作用】図４に、図３の発光素子における第一のｎ型層であるｎ型コンタクト層３から、活性層５に供給される電子の流れを模式的に示す。これは、ｎ型コンタクト層３から供給される電子が、矢印に示すように電子キャリア濃度の大きい第二のｎ型層３３中を通って均一に広がることにより活性層５を均一に発光させることを示している。このように第一のｎ型層に接して、その第一のｎ型層よりも電子キャリア濃度の大きい第二のｎ型層３３を活性層側に形成すると、電子が第二のｎ型層３３中に均一に広がるので、活性層５から均一な面発光が得られる。

【００１４】第二のｎ型層３３はインジウムを含む$In_XAl_YGa_{1-X-Y}N$（０＜Ｘ、Ｙ≦０）とすることが好ましく、特に好ましくはＩｎのＧａに対する混晶比（Ｉｎ／Ｇａ）が０．５以下のＩｎＧａＮとするのがよい。なぜなら、Ｉｎを含む窒化ガリウム系化合物半導体の方が、含まないものよりも電子キャリア濃度の大きい層を形成しやすく、またＩｎを含む結晶は、含まない結晶に比べて結晶が柔らかく、転位などの結晶欠陥を吸収しやすい。そのため基板上にＡｌＧａＮ、ＧａＮ等の格子整合していない第一のｎ型層３を成長させた場合、その第一のｎ型層３の結晶欠陥を第二のｎ型層３３で緩和することが可能であるからである。

【００１５】第二のｎ型層３３の電子キャリア濃度は$1\times10^{18}/cm^3$～$1\times10^{22}/cm^3$の範囲に調整することが好ましく、また第二のｎ型層３３よりも電子キャリア濃度の小さい第一のｎ型層は$1\times10^{16}/cm^3$～$1\times10^{19}/cm^3$の範囲に調整することが好ましい。これらの電子キャリア濃度は、前記のように第二のｎ型層にＳｉ、Ｇｅ、Ｓｎ、Ｃ等のｎ型ドーパントをドープすることにより調整可能である。第二のｎ型層３３の電子キャリア濃度が$1\times10^{18}/cm^3$よりも小さいと、電子を広げる作用が得られにくくなり均一な活性層の発光が得られにくく、$1\times10^{22}/cm^3$よりも大きいと結晶性が悪くなり、発光素子の性能に悪影響を及ぼす恐れがある。また第一のｎ型層についても電子キャリア濃度が$1\times10^{16}/cm^3$よりも小さいと活性層自体の発光が得られにくく、また$1\times10^{19}/cm^3$よりも大きいと１μｍ以上の厚膜を形成した際に結晶性が悪くなる傾向にあり、素子の出力を低下させる恐れがあるからである。

【0016】第二のｎ型層３３の膜厚は通常１０オングストローム～１μｍの膜厚で、さらに好ましくは５０オングストローム～０．３μｍの膜厚で形成することが好ましい。１０オングストロームよりも薄いと結晶性が不十分となるので、電子を広げる作用が得られにくくなり均一な活性層の発光が得られにくく、また１μｍよりも厚いと結晶欠陥が第二のｎ型層中に発生しやすくなり結晶性が悪くなるので、発光素子の性能を悪化させる恐れがある。

【0017】さらに、第二のｎ型層３３はＩｎ、Ｇａ、Ａｌの組成比が異なる窒化ガリウム系化合物半導体を２層以上積層した多層膜としてもよい。多層膜とする際の各層の膜厚も１０オングストローム～１μｍ、さらに好ましくは５０オングストローム～０．３μｍの多層膜とすることが好ましい。この第二のｎ型層３３を多層膜とすることにより、第一のｎ型層の結晶欠陥を多層膜層で止めると共に、格子整合していない窒化ガリウム系化合物半導体を積層した際の結晶中の歪を緩和して、結晶性に優れた半導体層を成長できるので発光素子の出力を向上させることができる。

【0018】次に、図５は本発明の他の実施例の発光素子の構造を示す模式断面図である。これは第一のｎ型層３に形成された負電極８と基板１との間に、第二のｎ型層３３が形成され、第二のｎ型層３３と負電極８との距離が接近していることを示している。本来であれば、電極８をキャリア濃度の大きい第二のｎ型層３３の表面に形成できれば、例えば図４と比較して、電子がキャリア濃度の大きい第二のｎ型層３３を通って流れるので、発光素子のＶｆを低下させることができる。しかしながら、サファイアのような絶縁性基板を用いた場合、エッチングを第二のｎ型層３３で止めることが生産技術上困難であるため、図５のように第二のｎ型層３３と負電極８との距離を短くして、電極８から注入された電子がキャリア濃度の大きい第二のｎ型層３３を通ることにより、Ｖｆを低下させることが可能となる。

【0019】さらに、サファイアを基板とし、そのサファイア基板の表面に少なくともｎ型層と、活性層と、ｐ型層とが順に積層されて、そのｐ型層と活性層とがエッチングされて露出されたｎ型層の表面に電極が形成される構造の発光素子においては、第二のｎ型層３３を、ｎ型層の電極形成面と基板との間に形成することにより効果的にＶｆを低下させることができる。なぜなら、ＳｉＣ、ＺｎＯ、Ｓｉ等の導電性基板の表面に窒化ガリウム系化合物半導体を成長した構造の発光素子であれば、ｎ型層の電極は基板側に形成でき、ｎ層側の電子は活性層に対し垂直に供給される。それに対し前記のようにサファイア基板を有する素子は、活性層に対し平行に供給される。垂直に供給される電子がｎ型層を移動する距離はせいぜい数μｍであるのに対し、平行に供給される電子の移動距離は数十μｍ～数百μｍもある。従って電子が

平行に供給される素子において、電子が平行に供給される第二のｎ型層のキャリア濃度を大きくすることにより、電子が移動しやすくなるのでＶｆを低下させることができる。

【0020】

【実施例】

［実施例１］ＭＯＶＰＥ法により、２インチφのサファイアよりなる基板１の表面に、ＧａＮよりなるバッファ層２を０．０２μｍの膜厚で成長させる。このバッファ層２の表面に第一のｎ型層として、Ｓｉをドープした電子キャリア濃度５×１０／^{18}cm^{3}のｎ型ＧａＮよりなるｎ型コンタクト層３を１μｍの膜厚で成長させる。

【0021】次にｎ型コンタクト層３の表面に第二のｎ型層として、Ｓｉをドープした電子キャリア濃度１×１０^{20}／cm^{3}のｎ型Ｉｎ0.1Ｇａ0.9N層を０．０５μｍの膜厚で成長させる。

【0022】次に同じくＳｉをドープした電子キャリア濃度５×１０^{18}／cm^{3}のＧａＮよりなるｎ型コンタクト層３’を３μｍの膜厚で成長させる。

【0023】ｎ型コンタクト層３’の表面に、Ｓｉをドープした電子キャリア濃度１×１０^{18}／cm^{3}のｎ型Ａｌ0.2Ｇａ0.8Nよりなるｎ型クラッド層を０．１μｍの膜厚で成長させ、その上にＳｉとＺｎドープｎ型Ｉｎ0.1Ｇａ0.9Nよりなる活性層５を０．１μｍと、ＭｇドープＡｌ0.2Ｇａ0.8Nよりなるｐ型クラッド層６と、ＭｇドープＧａＮよりなるｐ型コンタクト層７を順に成長させて積層する。

【0024】以上のようにして得たウェーハをアニーリング装置に入れ、７００℃でアニーリングして、ｐ型クラッド層６およびｐ型コンタクト層７をさらに低抵抗なｐ型とした後、ｐ型コンタクト層７の表面に所定の形状のマスクを形成し、ｐ型コンタクト層側からエッチングを行い、ｎ型コンタクト層３’を露出させる。

【0025】後は常法に従い、ｐ型コンタクト層７に正電極９と、露出したｎ型コンタクト層３’に負電極８を形成した後、チップ状に分離して、図５に示すような構造の青色発光素子とした。この発光素子発光させたところ、活性層５から主発光波長４５０ｎｍの均一な面発光が観測され、順方向電流（Ｉｆ）２０ｍＡにおいて、Ｖｆは３．３Ｖであり、発光出力は１．８ｍＷであった。

【0026】［実施例２］バッファ層２の表面に、第一のｎ型層として電子キャリア濃度１×１０^{18}／cm^{3}のＧｅドープＧａＮよりなるｎ型コンタクト層３を１μｍの膜厚で成長し、その表面に電子キャリア濃度５×１０^{20}／cm^{3}のＧｅドープＩｎ0.2Ｇａ0.8Nよりなる第二のｎ型層を０．０１μｍの膜圧で成長させる。次に第二のｎ型層３３の表面に同じく電子キャリア濃度１×１０^{18}／cm^{3}のＧｅドープｎ型ＧａＮよりなるｎ型コンタクト層３’を２μｍと、電子キャリア濃度５×１０^{20}／cm^{3}のＧｅドープｎ型Ｉｎ0.2Ｇａ0.8Nよりなる第二のｎ型層

３３’を０．０１μmと、電子キャリア濃度1×10^{18}／cm^3のＧｅドープｎ型ＧａＮ層とを１μmの膜厚で順に成長させる。

【００２７】後は実施例１と同様にしてｎ型クラッド層４、活性層５、ｐ型クラッド層６、ｐ型コンタクト層７を積層して、図６に示すような構造の青色発光素子とした。但し、図６に示すように、ｐ型コンタクト層７からのエッチング深さはｎ型コンタクト層３’までとし、負電極８はｎ型コンタクト層３’の表面に形成した。そして、この発光素子を発光させたところ、実施例１と同様に活性層５からは均一な面発光が観測され、Ｉｆ２０ｍＡにおいてＶｆ３．２Ｖ、発光出力は２．０ｍＷであった。

【００２８】［実施例３］バッファ層２の表面に、第一のｎ型層として電子キャリア濃度1×10^{18}／cm^3のＳｉドープ$Al_{0.1}Ga_{0.9}N$よりなるｎ型コンタクト層３を３μmの膜厚で成長させる。次にその表面に、電子キャリア濃度1×10^{20}／cm^3のＳｉドープ$In_{0.2}Ga_{0.8}N$を０．０１μmと、電子キャリア濃度1×10^{20}／cm^3のＳｉドープ$Al_{0.05}Ga_{0.95}N$を０．０１μmとを、それぞれ交互に５層づつ積層した第二のｎ型層３３を成長させる。

【００２９】次に第二のｎ型層３３の表面に、ＳｉとＺｎドープｎ型$In_{0.1}Ga_{0.9}N$よりなる活性層５を０．１μmと、Ｍｇドープ$Al_{0.2}Ga_{0.8}N$よりなるｐ型クラッド層６と、ＭｇドープＧａＮよりなるｐ型コンタクト層７を順に成長させて積層する。つまり、実施例１のｎ型クラッド層４を成長させない他は同様にして活性層５、ｐ型クラッド層６、ｐ型コンタクト層７を成長させる。後は実施例１と同様にしてエッチングを行い、図３に示すような構造の発光素子とした。この発光素子を発光させたところ同様に活性層５からは均一な面発光が得られ、Ｉｆ２０ｍＡにおいて、Ｖｆ３．５Ｖであり、発光出力は２．２ｍＷであった。

【００３０】［比較例１］実施例１において、第二のｎ型層３３を成長させず、ＧａＮコンタクト層を連続的に４μmの膜厚で成長させる他は同様にして、図１に示すような構造の発光素子とした。この発光素子の活性層は、図２に示すように正電極９と、負電極８との間で強く発光し、均一な発光を得ることができなかった。またＩｆ２０ｍＡにおいて、Ｖｆは３．６Ｖ、発光出力１．２ｍＷであった。

【００３１】

【発明の効果】以上説明したように、本発明の発光素子は全て活性層から均一な面発光を得て発光出力の向上した素子を実現できる。また、実施例１、２のように第二のｎ型層３３を負電極８と、基板１との間に形成した発光素子は、明らかにＶｆが低下している。また実施例３は第二のｎ型層が基板と負電極との間にないので、Ｖｆは低下に関しては影響が少ないが、第二のｎ型層を多層膜としているので、活性層、ｐ型クラッド層、ｐ型コンタクト層の結晶欠陥が少なくなり、発光出力が向上している。このように本発明の発光素子はキャリア濃度の大きい第二のｎ型層が第一のｎ型層に接して活性層側に形成されていることにより、均一な面発光を得て、発光出力の向上した素子を実現することができる。

【図面の簡単な説明】

【図１】 従来の発光素子の構造を示す模式断面図。

【図２】 図１の発光素子の発光状態を示す模式断面図。

【図３】 本発明の一実施例の発光素子の構造を示す模式断面図。

【図４】 図３の発光素子の発光状態を示す模式断面図。

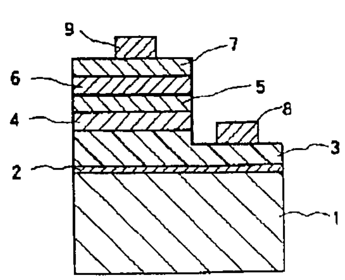
【図５】 本発明の他の実施例の発光素子の発光状態を示す模式断面図。

【図６】 本発明の他の実施例の発光素子の構造を示す模式断面図。

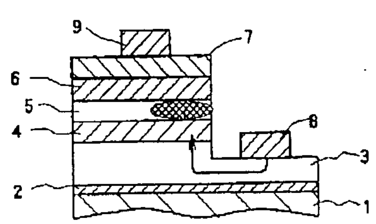
【符号の説明】

１・・・・・基板　２・・・・・バッファ層
４・・・・・ｎ型クラッド層　５・・・・・活性層
６・・・・・ｐ型クラッド層　７・・・・・ｐ型コンタクト層
８・・・・・負電極　９・・・・・正電極
３、３’、３”・・・・・第一のｎ型層（ｎ型コンタクト層）
３３、３３’・・・・・第二のｎ型層

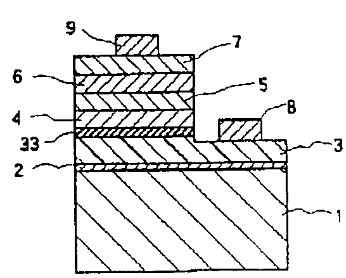
【図１】



【図２】

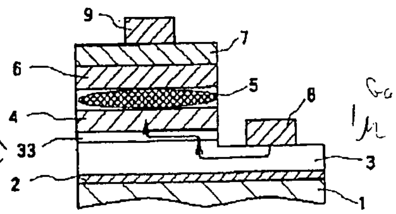


【図３】



50nm InGaN

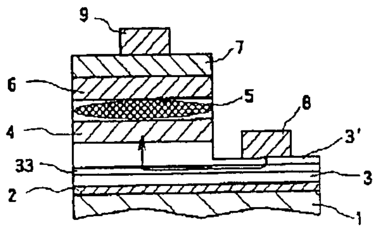
【図４】



GaN or AlGaN
10A – 500nm

【図５】

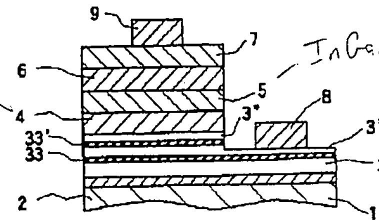
GaN
1μ



AlGaN clad

【図６】

InGaN active



33 n doped > 3

[0014] 33 InGaAlN eg $In_{.5}GaN$

[0015] 3 (Al)GaN

[0017] 2nd may be multilayer

[0016] pref

1e18 – 1e22　10A – 1μ　50A – 0.3μ

1e16 – 1e19　1–5μ

[0010]

3　GaN　1e18　1μ

33'　$In_{.2}GaN$　5e20　10nm

3'　2μ?　GaN　1e18

33　10nm　$In_{.2}GaN$　5e20

3　1μ　GaN　1e18

3 appears to be 1–3μ ∴ not "thin"?

PATENT ABSTRACTS OF JAPAN

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H01S 3/18

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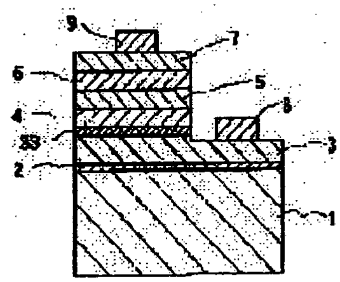
(71)Applicant : NICHIA CHEM IND LTD
(72)Inventor : NAKAMURA SHUJI

(54) LIGHT-EMITTING ELEMENT OF GALLIUM NITRIDE COMPOUND SEMICONDUCTOR

(57)Abstract:
PURPOSE: To improve light-emitting efficiency by obtaining uniform light mission from an active layer, improving the luminosity and output of the lement and further lowering Vf of the light-emitting element.
CONSTITUTION: In a gallium nitride compound semiconductor light-emitting lement having a structure in which at least an n-type layer is formed between an active layer and a substrate, said n-type layer contains a first n-type layer 3 formed at the substrate side and also contains a second n-type layer 33 having electron density larger than in the first n-type layer 3 formed at the side of an active layer 5 in contact with the first n-type layer 3.



LEGAL STATUS

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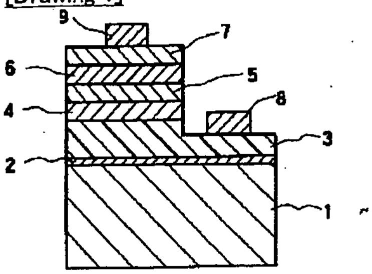
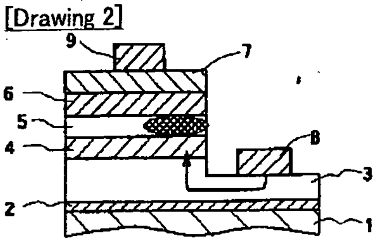
[Date of extinction of right]	

DRAWINGS

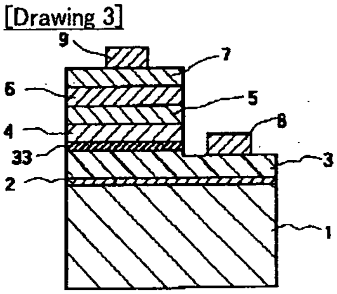
[Drawing 1]



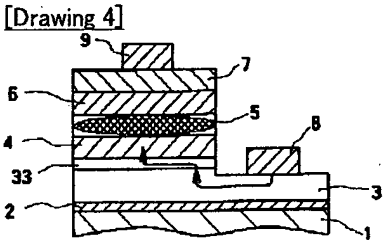
[Drawing 2]



[Drawing 3]

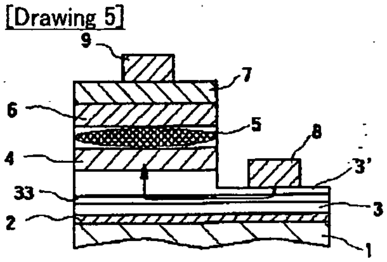


[Drawing 4]

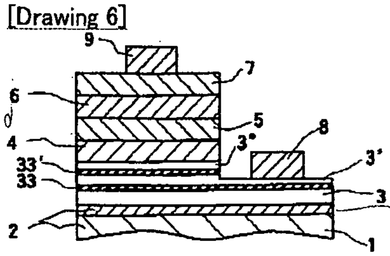


$n_{33} > n_3$

[Drawing 5]



[Drawing 6]



n clad

3μ

GaN or AlN

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The type section view showing the structure of the conventional light emitting device.
[Drawing 2] The type section view showing the luminescence state of the light emitting device of drawing 1 .
[Drawing 3] The type section view showing the structure of the light emitting device of one example of this invention.
[Drawing 4] The type section view showing the luminescence state of the light emitting device of drawing 3 .
[Drawing 5] The type section view showing the luminescence state of the light emitting device of other examples of this invention.
[Drawing 6] The type section view showing the structure of the light emitting device of other examples of this invention.
[Description of Notations]
1 ..... Substrate 2 ..... Buffer layer
4 ..... n type clad layer 5 ..... Barrier layer
6 ..... p type clad layer 7 ..... p type contact layer
8 ..... Negative electrode 9 ..... Positive electrode
3, 3', 3″ ..... First n type layer (n type contact layer)
33 33' ..... Second n type layer

[Translation done.]

second n type layer 33, and continuously grown up a GaN contact layer by 4-microm ter thickness and also similarly shown in drawing 1 . The barrier layer of this light emitting devic emitted light strongly b tween the positiv lectrode 9 and the negative electrode 8, as shown in drawing 2 , and it was not able to obtain uniform luminescence. Mor over, in If20mA, Vf(s) were 3.6V and 1.2mW of radiant power outputs.

[0031]

[Effect of the Invention] As explained above, all th light emitting devices of this invention can r alize the element which obtained uniform field luminesc nce from th barrier layer, and improved. Moreov r, as for th light emitting device which formed second n type layer 33 between the negative electrode 8 and the substrate 1 like xamples 1 and 2, Vf is falling clearly. Moreover, since an exampl 3 does not have s cond n type layer between a substrate and a n gative l ctrode, although there is little influence about a fall, since second n type layer is mad into the multilayer, the crystal defect of Vf of a barrier layer, p type clad layer, and p type contact layer decreases, and a radiant power output's is improving. Thus, by forming second n type layer with large carrier concentration in the barrier-layer side in contact with first n type layer, the light emitting device of this invention can obtain uniform field luminescence, and can realize the element which improved.

[Translation done.]

an electron will flow through second n typ lay r 33 with large carrier conc ntration, for example as compared with drawing 4 if it is original, and an electrode 8 can b formed in the front face of second n type lay r 33 with larg carrier concentration, Vf of a light emitting devic can b reduc d. However, since an IE top is difficult for stopping etching in second n type layer 33 when an insulating substrate like sapphire is used, when distance of second n type lay r 33 and a negative lectrode 8 is shortened like drawing 5 and th lectron poured in from the electrode 8 passes along second n type layer 33 with large carrier concentration, it becomes possible to reduce Vf.

[0019] Sapphire is used as a substrate. at least on th front face of the silicon on sapphir Furthermore, n type layer, In the light mitting devic of the structure wh r an el ctrode is form d in the front face of n type layer on which the laminating of a barri r layer and the p type layer was carried out to order, it **********ed and the p type layer and barrier layer wer exposed Vf can be effectively reduc d by forming second n type layer 33 betw en the electrode forming face of n type layer, and a substrate. Because, if it is the light emitting d vice of structure which gr w up the gallium-nitrid system compound semiconductor to be the front face of conductive substrates, such as SiC, ZnO, and Si, the electrode of n type layer can be formed in a substrate side, and the electron by the side of n layers will be perpendicularly supplied to a barrier layer. The element which has silicon on sapphire as mentioned above to it is supplied in parallel to a barrier layer. The electron-transfer distance supplied in parallel also has dozens of micrometers - hundreds of micrometers to the distance to which the electron supplied perpendicularly moves n type layer being several [at most] micrometers. Therefore, in the element to which an electron is supplied in parallel, by enlarging carrier concentration of second n type layer to which an electron is supplied in parallel, since it becomes easy to move an electron, Vf can be reduced.

[0020]

[Example]

The buffer layer 2 which becomes the front face of the substrate 1 which consists of sapphire of 2 inch phi from GaN by the [example 1] MOVPE method is grown up by 0.02-micrometer thickness. The electronic carrier concentration 5x10 / n type contact layer 3 which consists of n type GaN of 3 18cm which doped Si is grown up into the front face of this buffer layer 2 by 1-micrometer thickness as first n type layer. 3 3e18 1μ

[0021] Next, the n mold In0.1Ga0.9N layer of 1x1020/of electronic carrier concentration cm 3 which doped Si is grown up into the front face of n type contact layer 3 by 0.05-micrometer thickness as second n type layer. (33) 50nm

[0022] Next, n type contact layer 3' which consists of GaN of 5x1018/of electronic carrier concentration cm 3 which similarly doped Si is grown up by 3-micrometer thickness. 5e18

[0023] n type clad layer which consists of n type aluminum0.2Ga0.8N of 1x1018/of electronic carrier concentration cm 3 which doped Si on the front face of n type contact layer 3' is grown up by 0.1-micrometer thickness. p type contact layer 7 which turns into 0.1 micrometers and p type clad layer 6 which consists of Mg dope aluminum0.2Ga0.8N from the Mg dope GaN in the barrier layer 5 which consists of Si and Zn dope n type In0.1Ga0.9N on it is grown up in order, and carries out a laminating. AlGaN Clad

[0024] the wafer obtained as mentioned above — annealing equipment — putting in — 700 degrees C — annealing — carrying out — p type clad layer 6 and p type contact layer 7 — further — low — after considering as p type [****], th mask of a predetermined configuration is formed in the front face of p type contact layer 7, etching is performed from p type contact layer side, and n type contact layer 3' is exposed

[0025] After the rest formed the negative electrode 8 in n type contact layer 3' exposed to p type contact layer 7 with the positive electrode 9 according to the conventional method, it dissociated in the shape of a chip, and it was made into the blue light emitting device of structure as shown in drawing 5 . When [this] carrying out light-emitting-device luminescence, uniform field luminescence with a main luminescence wavelength of 450nm was observed from the barrier layer 5, in forward-current (If)20mA, Vf was 3.3V and the radiant power output was 1.8mW.

[0026] n type contact layer 3 which becomes the front face of the [example 2] buffer layer 2 from the germanium dope GaN of electronic carrier concentration 1x1018-/cm3 as first n type layer is grown up by 1-micrometer thickness, and second n type layer which becomes from germanium dope In0.2Ga0.8N of electronic carrier concentration 5x1020-/cm3 at the front face is grown up by 0.01-micrometer film pressure. n type contact layer 3' which consists of germanium dope n type GaN of 1x1018/of electronic carrier concentration cm 3 as well as the front face of second n type layer 33 Next, 2 micrometers, Second n type layer 33' which consists of germanium dope n type In0.2Ga0.8N of 5x1020/of electronic carrier concentration cm 3 grows up 0.01 micrometers and the germanium dope n type GaN layer of 1x1018/of electronic carrier concentration cm 3 in order by 1-micrometer thickness.

[0027] The rest carried out the laminating of n type clad layer 4, a barrier layer 5, p type clad layer 6, and the p type contact layer 7 like the example 1, and made them the blue light emitting device of structure as shown in drawing 6 . How ver, as shown in drawing 6 , the etching depth from p type contact layer 7 was carried out to to n type contact layer 3', and the negative electrode 8 was formed in the front face of n type contact layer 3'. And when this light emitting devic was made to emit light, from the barrier layer 5, uniform field luminescence was observed like the example 1, and Vf3.2V and the radiant power output were 2.0mW in If20mA.

[0028] n type contact layer 3 which becomes the front face of the [example 3] buffer layer 2 from Si dope aluminum0.1Ga0.9N of electronic carrier concentration 1x1018-/cm3 as first n type layer is grown up by 3-micrometer thickness. N xt, second n type layer 33 which made 0.01 micrometers and Si dope aluminum0.05Ga0.95N of 1x1020/of el ctronic carrier concentration cm 3 the front face for Si dope In0.2Ga0.8N of 1x1020/of electronic carrier concentration cm 3, and made the laminating of the 0.01 micrometers five layers at a time by turns, respectively is grown up.

[0029] Next, p type contact layer 7 which turns into 0.1 micrometers and p type clad layer 6 which consists of Mg dope aluminum0.2Ga0.8N from the Mg dope GaN in the barri r layer 5 which consists of Si and Zn dope n type In0.1Ga0.9N is grown up into the front face of second n type layer 33 in order, and carries out a laminating to it. That is, n type clad layer 4 of an example 1 is not grown up, and also a barrier layer 5, p type clad layer 6, and p type contact layer 7 are grown up similarly. The rest etched like the example 1 and was made into the light emitting device of structure as shown in drawing 3 . Uniform field luminescence was obtained from the barrier layer 5 like the place which made this light emitting device emit light, in If20mA, it was Vf3.5V and the radiant power output was 2.2mW.

type clad lay r 6 and p type contact lay r 7 as single p type layer.

[0009] In th light emitting devic of this inv ntion, in ord r to grow up the gallium-nitride syst m compound semiconductor layer excellent in crystallinity, it is desirable to use sapphire for a substrate 1 pref rably, to grow up GaN or AlN into a buffer layer 2, and to form by 10A - 0.5 micrometers thickness.

[0010] In usually forming first n type lay r formed between a barrier layer 5 and a substrate 1 by 1 micrometer - 5 micrometers thickness as an n type contact layer 3 and forming n typ clad layer 4 in the front face, it grows up by 50A - 1 micrometer thickness. However, it is not nec ssary to form specially this n type clad layer 4 as m ntioned above. As a gallium-nitrid system compound semiconductor, GaN and AlGaN ar desirable and set to GaN most pr ferably. Because, it is asy for GaN and AlGaN to dope a non dope or n type dopant, to serve as n type asily, and to control electronic carri r concentration by the dopant. GaN tends [furthermore] to grow for [AlGaN] forming a crystalline good thick film by the monolayer. For example, although it is necessary to remov p typ layer by etching and to expose n typ contact layer 3 in order to form the electrode 8 of n type contact layer 3 when the element which carried out the laminating of n type layer and the p type layer to order by using sapphire as a substrate is realized, it is very convenient in case an actual element will be realized since there is the degree of ** of the etching depth if a thick film can be formed by the monolayer.

[0011] Next, as for a barrier layer 5, it is desirable to usually grow up by 50A - 0.5 micrometers thickness, and to be ref rred to as InGaN. It is also easy for InGaN to be able to change the luminescence wavelength of a light emitting devic asily to purple - green by the mixed-crystal ratio of an indium using luminescence between bands, to dope n type and a p type dopant further, and to consider as an emission center. As for the mixed-crystal ratio (In/Ga) to Ga of In, it is still more desirable that it is 0.5 or less. Since more InGaN(s) than 0.5 do not have good crystallinity, they are in the inclination it to become difficult to obtain a practical light emitting device. It is desirable that n type dopant and p type dopant are doped as a most excellent barrier layer, consider as n type, and In mixed-crystal ratio to Ga makes 0.5 or less InGaN a barrier layer.

[0012] p type layer which grows on a barrier layer 5 also has GaN and desirable AlGaN, p type clad layer 6 is formed by 50A - 1 micrometer thickness, and p contact layer 7 grows by 50A - 5 micrometers thickness. However, it is not necessary to make especially this p type clad layer 6 form. When a crystalline good thick film tends to grow by the monolayer, and these which form GaN and AlGaN preferably as a gallium-nitride system compound semiconductor dope p type dopant and anneal it above 400 degrees C, they are in the inclination which serves as p type easily.

[0013]

[Function] The electron flow supplied at a barrier layer 5 is typically shown in drawing 4 from n type contact layer 3 which is first n type layer in the light emitting device of drawing 3 . This shows making a barrier layer 5 emit light uniformly, when the electron supplied from n type contact layer 3 spreads [be / under / n type layer / with large electronic carrier concentration / of ** a second / 33 / passing / it] uniformly, as shown in an arrow. Thus, if first n type layer is touched and second n type layer 33 with larger electronic carrier concentration than the first n type layer is formed in a barrier-layer side, since an electron will spread uniformly in second n type layer 33, uniform field luminescence is obtained from a barrier layer 5.

[0014] As for second n type layer 33, it is good that it is desirable especially desirable to consider as InXAlYGa1-X-YN (0<X, Y<=0) containing an indium, and the mixed-crystal ratio (In/Ga) to Ga of In sets to 0.5 or less InGaN. Because, compared with the crystal which the crystal the gallium-nitride system compound semiconductor containing In tends to form [whose] a layer with larger electronic carrier concentration than what is not included, and it contains In does not include, a crystal is soft and it is easy to absorb crystal defects, such as dislocation. Therefore, it is because it is possible to ease the crystal defect of the first n type layer 3 in second n type layer 33 when growing up first n type layer 3 which has not carried out grid adjustment, such as AlGaN and GaN, on a substrate.

[0015] As for first n type layer with electronic carrier concentration smaller than second n type layer 33 with desirable [the electronic carrier concentration of second n type layer 33] and adjusting to the range of three to 1x1022/cm3 of 1x1018-/cm, it is desirable to adjust to the range of three to 1x1019/cm3 of 1x1016-/cm. Such electronic carrier concentration can be adjusted by doping n type dopants, such as Si, germanium, Sn, and C, in second n type layer as mentioned above. The operation which extends an electron becomes will be hard to be obtained if the electronic carrier concentration of second n type layer 33 is smaller than 1x1018-/cm3, luminescence of a uniform barrier layer is hard to be obtained, if larger than 1x1022-/cm3, crystallinity will become bad, and there is a possibility of having a bad influence on th performance of a light emitting device. Moreover, it is because luminescence of the barrier layer itself will be hard to be obtained if electronic carrier concentration is smaller than 1x1016-/cm3 also about first n type layer, and it is in the inclination for crystallinity to become bad when larger [than 1x1019/cm3] and a thick film 1 micrometers or more is formed, and there is a possibility of reducing the output of an element.

[0016] The thickness of second n type layer 33 is usually 10A - 1 micrometer thickness, and it is desirable to form by 50A - 0.3 micrometers thickness still more preferably. Since the operation which extends an electron becomes is hard to be obtained since crystallinity will become inadequate if thinner than 10A, and luminescence of a uniform barrier layer is hard to be obtained, and it will become easy to generate a crystal defect in second n type layer if thicker than 1 micrometer, and crystallinity becomes bad, there is a possibility of worsening the performance of a light emitting device.

[0017] Furthermore, second n typ layer 33 is good also as a multilayer which carried out the laminating of the gallium-nitride system compound semiconductor from which the composition ratio of In, Ga, and aluminum differs more than two-layer. It is desirable to also mak still more preferably 10A - 1 micrometer also of thickness of each class at the time of considering as a multilayer into a 50A - 0.3 micrometers multilayer. While stopping the crystal defect of first n type layer in a multilayer layer by making this s cond n type layer 33 into a multilayer, the distortion under crystal at the time of carrying out the laminating of the gallium-nitride system compound semiconductor which has not carried out grid adjustment is eased, and since the semiconductor layer excellent in crystallinity can be grown up, the output of a light emitting device can be raised.

[0018] Next, drawing 5 is the type section view showing the structure of the light emitting d vice of other examples of this invention. Second n type layer 33 is formed between the negative el ctrodes 8 and substrates 1 which were formed in first

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Industrial Application] this invention relates to the light emitting device which consists of a gallium-nitride system compound semiconductor (InaAlbGa1-a-bN, 0<=a, 0<=b, a+b<=1) used for light emitting devices, such as a laser diode (LD) and light emitting diode (Light Emitting Diode).

[0002]

[D scription of the Prior Art] Now, blue Light Emitting Diode with a luminous intensity of 1 cd put in practical use consists of a gallium-nitride system compound semiconductor (InaAlbGa1-a-bN, 0<=a, 0<=b, a+b<=1), and has the structure shown in drawing 1 . It is terrorism structure in the double by which the laminating of the buffer layer 2 which becomes the front face of the substrate 1 which consists of sapphire from GaN, n type layer 3 which consists of GaN, n type clad layer 4 which consists of AlGaN, the barrier layer 5 which consists of InGaN, p type clad layer 6 which consists of AlGaN, and the p typ contact layer 7 which consists of GaN was carried out to order. This blue Light Emitting Diode indicates the highest ever p rformances to be forward voltage (Vf)3.6V, the peak emission wavelength of 450nm, the luminous intensity of 1 cd, and 1.2mW of radiant power outputs by blue Light Emitting Diode in forward-current (If)20mA.

[0003] In Light Emitting Diode of the aforementioned structure, although a substrate 1 has usable material other than sapphire, such as ZnO, SiC, GaAs, and Si, generally sapphire is used. As for a buffer layer 2, GaAlN besides GaN, AlN, etc. ar formed. n type contact layer 3 and n type clad layer 4 are formed in a gallium-nitride system compound semiconductor by the gallium-nitride system compound semiconductor which doped n type dopants, such as Si, germanium, Sn, and C. Moreover, even if it does not divide n type contact layer 3 and n type clad layer 4 into a bilayer in this way, you may make them act as a clad layer and a contact layer as a single n type layer (it is got blocked and one of layers can be omitted). A barrier layer 5 consists of a gallium-nitride system compound semiconductor which contains an indium at least, and p type dopant and/or n type dopants, such as a non dope, and Zn, Mg, Cd, Be, are doped. After p type clad layer 6 and p type contact layer 7 dope p type dopant to a gallium-nitride system compound semiconductor, let them be p type by carrying out annealing above 400 degrees C. Moreover, you may make p type clad layer 6 and p type contact layer 7 act as a clad layer and contact layers as single p type layers (an ellipsis of one of layers is possible like n layers).

[0004]

[Problem(s) to be Solved by the Invention] In the case of the gallium-nitride system compound semiconductor, compared with III-V group compound semiconductors, such as other GaAs(es), GaP, and AlInGaP, it has the property in which current generally cannot spread easily uniformly. Then, when the Light Emitting Diode element of structure like drawing 1 is r alized, there is a problem that the electron flow supplied to a barrier layer from n layers will concentrate on the low part of resistance. Drawing 2 shows luminescence of the barrier layer by concentration of current typically. As the electron supplied from the negative electrode 8 of n type contact layer 3 shows the arrow of drawing 2 , this means emitting light strongly partially, as a barrier layer 5 shows the nearest distance in the half-tone-dot-meshing section by flowing so that r sistance between the positive electrode 9 of p type contact layer 7 and the negative electrode 8 of n type contact layer 3 may become low. Thus, if an electron does not spread uniformly in n type contact layer 3, there is a fault that uniform luminescence is not obtained from a barrier layer 5.

[0005] Moreover, Light Emitting Diode of the above-mentioned structure reduced more than 5VVf compared with blue Light Emitting Diode set to Vf3.6V from the gallium-nitride system compound semiconductor of the conventional MIS structur . Although this shows luminescence by p-n junction, there is room to still improve also about Vf and the further fall of Vf is d sired.

[0006] Therefore, the place which this invention is made in view of such a situation, is a thing, and is made into the purpose In the gallium-nitride system compound semiconductor light emitting device which is equipped with terrorism to double and equipped with the structures where n type layer was formed between the barrier layer and the substrate at least, such as terrorism, to a single First, luminescence more uniform than a barrier layer is obtained in the first place, it is in raising the luminous intensity of an element; and an output, Vf is reduced [second] further, and it is in raising luminous efficiency.

[0007]

[Means for Solving the Problem] By making a layer with still higher carrier concentration placed between n type layers, we found out that the above-mentioned problem was solvable. Namely, the gallium-nitride system compound semiconductor light emitting device of this invention In a gallium-nitride system compound semiconductor light emitting devic equipp d with the structure where n type layer was formed between the barrier layer and the substrate at least It is charact riz d by the aforementioned n typ layer containing second n type lay r with larger electronic carrier concentration than first n type layer by being form d in a barrier-layer side in contact with the first n type layer and first n type layer formed in the substrate side.

[0008] The structure of the light emitting device of one example of this invention is shown in drawing 3 . Although fundamental structure is almost the same as the light emitting device shown in drawing 1 , n type contact layer 3 which is first n type layer is touched, and second new n type layer 33 with larger electronic carrier concentration than the first n type layer 3 is formed in a barri r-layer 5 side. A substrate 1, a buffer layer 2, n type contact layer 3, n type clad layer 4, a barrier layer 5, p type clad layer 6, and p type contact layer 7 grade can be formed by the gallium-nitride system compound

CLAIMS

[Claim(s)]
[Claim 1] The gallium-nitride system compound semiconductor light emitting device equipped with the structure where n type layer was formed between the barrier layer and the substrate at least characterized by providing the following. The aforementioned n type layer is first n type layer formed in the substrate side. Second n type layer with electronic carrier concentration it is formed in a barrier-layer side in contact with the first n type layer, and larger than first n type layer.
[Claim 2] The gallium-nitride system compound semiconductor light emitting device according to claim 1 characterized by the bird clapper from the gallium-nitride system compound semiconductor ($In_XAl_YGa_{1-X-Y}N$, $0<X$, $0<=Y$, $X+Y<=1$) in which n type layer of the above second contains an indium at least.
[Claim 3] n type layer of the above second is a gallium-nitride system compound semiconductor light emitting device according to claim 1 or 2 to which the gallium-nitride system compound semiconductor layer from which composition differs mutually is characterized by the bird clapper from the multilayer by which the laminating was carried out more than two-layer.

[Translation done.]

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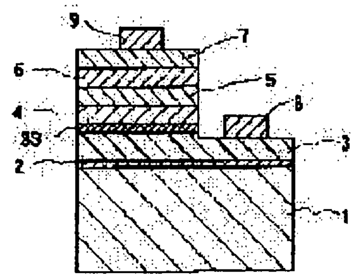
(54) LIGHT-EMITTING ELEMENT OF GALLIUM NITRIDE COMPOUND SEMICONDUCTOR

(57)Abstract:
PURPOSE: To improve light-emitting efficiency by obtaining uniform light emission from an active layer, improving the luminosity and output of the element and further lowering Vf of the light-emitting element.
CONSTITUTION: In a gallium nitride compound semiconductor light-emitting element having a structure in which at least an n-type layer is formed between an active layer and a substrate, said n-type layer contains a first n-type layer 3 formed at the substrate side and also contains a second n-type layer 33 having electron density larger than in the first n-type layer 3 formed at the side of an active layer 5 in contact with the first n-type layer 3.



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GALIUM NITRIDE TYPE OF COMPOUND SEMICONDUCTOR LIGHT EMITTING ELEMENT

(Chikka gariumu kei ka kago butsu hadotai hatsu ko soshi)

Shuichi Nakamura et al

UNITED STATES PATENT AND TRADEMARK OFFICE

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/1[1]

[Title of Invention] Gallium nitride type of compound semiconductor light emitting element

[Summary]

[Purpose] To obtain a uniform light emitting from the active layer and to improve the brightness of the element and to improve the output. Also, to reduce further the Vf in the light emitting element, the light emitting efficiency can be improved.

[Constitution] In a Gallium nitride type of compound semiconductor light emitting element that is provided with a structure that consists of at least one n- type layer formed between the active layer and the substrate, the aforementioned n type layer consists of the 1st n type layer 3 that is formed at the substrate side and the 2nd n type layer 33 that is formed at the active layer 5 side that is touching that 1st n type layer 3. It has higher concentration of electron carriers than the 1st n type layer 3.

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[Scope of Patent Claims]

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[1] Numbers in the margin indicate pagination in the foreign text.

[Claim 1] In a Gallium nitride type of compound semiconductor light emitting element that is provided with a structure that consists of at least one n- type layer formed between the active layer and the substrate, the aforementioned n type layer consists of the 1st n type layer that is formed at the substrate side and the 2nd n type layer that is formed at the active layer side that is touching that 1st n type layer. It has higher concentration of electron carriers than the 1st n type layer.

[Claim 2] The aforementioned 2nd n type layer in the nitride gallium type compound semiconductor light emitting element stated in Claim 1 is characterized as being made from gallium nitride type compound semiconductor (InxAlYGa 1-x-yN, 0<X, 0<Y, X+Y<1) containing at least one of this, Indium.

[Claim 3] The aforementioned 2nd n type layer in the nitride gallium type compound semiconductor light emitting element stated in Claim 1 or Claim 2 is characterized as being made from gallium nitride type compound semiconductor consisting of lamination of above 2 layers of different composition.

[Detailed explanation of the invention]

[0001]

[Industrial field of use] The invention pertains to a light emitting element made from gallium nitride type compound

semiconductor (InaAlbGa 1-a-bN, 0<a, 0<b, a+b<1) used in the light emitting element such as light emitting diode (LED) and laser diode (LD).

[0002]

[Prior Art] At present, the blue color LED of light emitting light of 1cd is made of gallium nitride type compound semiconductor (InaAlbG a 1-a-bN, 0<a, 0<n, a+b<1), its structure is shown in figure 1. The double hetero structure is laminated respectively with the following layers on the top surface of the substrate 1 made of sapphire, that is, the buffer layer 2 made from GaN, the n type layer 3 made from GaN, the n type clad layer 4 made from AlGaN, the active layer 5 made from InGaN, the p type clad layer 6 made from AlGaN and the p type contact layer 7 made from GaN. This blue color LED has sequence direction current flow (If) of 20 mA, the sequence direction voltage (Vf) is 3.6 V, the peak light emitting wavelength is 450 nm, the degree of light emitting is 1cd, the light generating output is 1.2 mW, the blue color LED shows excess high performance.

[0003] In the LED of the aforementioned structure, the materials given as follows can be used instead of the sapphire for the substrate 1, for example, ZnO, SiC, GaAs, Si. However, in general, sapphire is used. The buffer layer

2 is formed with GaALN, ALN in addition to GaN. The n type contact layer 3, the n type clad layer 4 are formed with the gallium nitride type compound semiconductor doped with the n type do-pant such as Si, Ge, Sn, C onto the gallium nitride type compound semiconductor. Also, the n type contact layer 3, the n type clad layer 4 acts as the clad layer and the contact layer and as the single n type layer not divided into two layer (then, either layer can be omitted). The active layer 5 is made from the gallium nitride type compound semiconductor that consists of indium, it is doped with the p type dopant and/or the n type of dopant such as Zn, Mg, Cd, Be or it is non-doped. After the p type clad layer 6 and the p type contact layer 7 are doped with the p type dopant on the gallium nitride type compound semiconductor, it is annealed above 400 degree C and becomes the p type. Also, the p type clad layer 6 and the p type contact layer 7 are acted as the single p type layer, the clad layer and the contact layer (any of these layers can be omitted similar to the n layer).

[0004]

[The problems resolved by the invention] The gallium nitride type compound semiconductor has non-uniform current flow as compared to the Group III - V compound

semiconductor such as GaAs, GaP, ALInGaP. When the LED element having the structure shown in Figure 1 is obtained, the flow of the electron supplied to the active layer from the n layer all concentrates in the location with low resistance which is a problem. Figure 2 show a typical model of the light emitting active layer due to the concentration of the current. The electron is supplied from the negative electrode 8 of the n type contact layer 3 as shown in the arrow of figure 2. The resistance between the positive electrode 9 of the p type contact layer 7 and the negative electrode 8 of the n type contact layer 3 is reduced. By flowing the current at a closer distance, the active layer 5 emits strong light partially shown with the net hanging part. Thus, the electrons are uniform at the n type contact layer 3 but the drawback is that uniform light emitting cannot be obtained from the active layer 5.

[0005] Also, the LED of the above structure has Vf3.6 V as compared to the blue color LED made from the gallium nitride type compound semiconductor of the conventional MIS structure which has Vf of above 5V. The light is emitted by the p - n bond so there is a need for the improvement of the Vf. In addition, the reduction of Vf is desired.

[0006] Therefore, the purpose of the invention is to focus on the above problems and offer a gallium nitride type

compound semiconductor light emitting element that is provided with a structure where the n type layer is formed between the active layer and the substrate such as the double hetero and the single hetero. Uniform light emitting can be obtained from the active layer. First, the brightness of the element and the output are improved. Second, the Vf is reduced and the light emitting efficiency is improved.

[0007]

[Means for resolving the problems] The purpose of the invention is to resolve the above problems by having a layer consisting of high concentration of electron carriers in the n type layer. That is, in a Gallium nitride type of compound semiconductor light emitting element that is provided with a structure that consists of at least one n-type layer formed between the active layer and the substrate, the aforementioned n type layer consists of the 1^{st} n type layer that is formed at the substrate side and the 2^{nd} n type layer that is formed at the active layer side that is touching that 1^{st} n type layer. It has higher concentration of electron carriers than the 1^{st} n type layer.

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[0008] The structure of the light emitting element of one implementation example of the invention is shown in figure 3. The basic structure is the same as the light emitting element shown in figure 1. It is placed close to the n type contact layer 3 which is the 1^{st} n type layer. The 2^{nd} n type layer 33 is formed with large electron carrier concentration than the 1^{st} n type layer 3, this is formed at the active layer 5 side. The gallium nitride type compound semiconductor is formed with a substrate 1, a buffer layer 2, the n type clad layer 4, an active layer 5, a p type clad layer 6, the p type contact layer 7. These are formed as a single layer, the n type clad layer 4 and the n type contact layer 3. Also, the p type clad layer 6 and the p type contact layer 7 can be the single layer p type.

[0009] In the light emitting element of the invention, it is preferred that sapphire is used for the substrate 1, the gallium nitride type compound semiconductor layer is grown having excellent crystallinity. GaN or AIN are grown on the buffer layer 2 and it is grown into a thickness of 10 angstroms - 0.5 μm.

[0010] The 1^{st} n type layer formed between the active layer 5 and the substrate 1 is formed into a standard thickness of 1 μm - 5 μm as the n type contact layer 3. When the n type clad layer 4 is formed on the top surface, the

thickness is 50 angstroms to 1 μm. Therefore, as mentioned above, it is preferred that this n type clad layer 4 is formed. It is preferred that GaN, ALGaN is used in the gallium nitride type compound semiconductor. The most preferred is GaN. GaN and AlGaN become the n type doped with the n type dopant or it is non-doped. The electron carrier concentration can be controlled easily by the dopant. In addition, GaN grow easily forming a thick single layer crystal from the AlGaN. For example, when the n type layer and the p type layer are laminated in this order on the sapphire substrate, the light emitting element is obtained. Since the electrode 8 is provided in the n type contact layer 3, the p type layer is removed by etching and the n type contact layer 3 must be exposed and a thickness of a single layer is formed. Since the etching depth is not fixed, a real element can be realized which is highly desirable.

[0011] Next, the active layer 5 is grown with a standard thickness of 50 angstroms - 0.5 μm, InGaN film is obtained. The light emitting wavelength of the light emitting element using the light emitted between the band by the indium crystals of InGaN mixture can be changed easily to red - green color. In addition, the n type and p type dopant are doped and it is used easily as the core for emitting the

light. In addition, it is preferred that the crystals mixture ratio (In/Ga) for the In in Ga is below 0.5. When the InGaN is more than 0.5, the crystallinity is poor and it tends to be difficult to obtain a light emitting element practically. An example of an excellent layer is the n type doped with the n type dopant and the p type dopant. The In crystal mixture ratio in Ga is below 0.5, the InGaN layer becomes the preferred active layer.

[0012] It is preferred that the P type layer GaN and AlGaN are grown on top of the active layer 5. The p type clad layer 6 is formed at a thickness of 50 angstroms - 1 μm. The p contact layer 7 is formed at a thickness of 50 angstroms - 5 μm. That is, this p type clad layer 6 is not formed in any special form. It is preferred that GaN, AlGaN are preferred to be formed as the gallium nitride type compound semiconductor. The film thickness can be grown easily in a single layer with good crystallinity. Also, the p type dopant is doped and it is annealed easily above 400 degree, this tends to become the p type.

[0013]

[Action] A typical model of the current flowing in the electrons are supplied to the active layer 5 from the n type contact layer 3 which is the 1st n type layer in the light emitting element of figure 3. Active layer 5 emits

uniform light by increasing the electrons uniformly via the 2nd n type layer 33 of large electron carrier concentration as shown in the direction of the arrow. This touches the 1st n type layer. When the 2nd n type layer 33 formed at the active layer side has large electron carrier concentration than the 1st n type layer at the 1st n type layer, since the electrons increased uniformly in the middle of the 2nd n type layer 33, a uniform light emitting surface is obtained from the active layer 5.

[0014] It is preferred that the 2nd n type layer 33 becomes the InxAlyGa1-x-yN (0<X, Y <0) containing Indium. In particular, it is preferred that the crystals mixture ratio (In/Ga) of the In in Ga is below 0.5, this InGaN mixture is preferred. In addition, the gallium nitride type compound semiconductor containing In can form easily the layer with a large concentration of electron carrier than the one not containing it. Also, the crystal containing the In has soft crystal than the one that do not contain any. The crystal flaw is absorbed easily like the rotation position. Therefore, when the 1st n type layer that do not contain the lattice of AlGaN and GaN grows the 1st n type layer 3 on the substrate, the crystal flow of that 1st n type layer 3 can be pacified with the 2nd n type layer 33.

[0015] The concentration of the electron carriers in the 2nd n type layer 33 is preferred to be adjusted in the range of $1 \times 10^{18}/cm^3$ - 1×10^{22} $/cm^3$. Also, it is preferred that the concentration of the electron carriers in the 1st n type layer that is smaller than that concentration in the 2nd n type layer 33 is preferred to be adjusted to the range of $1 \times 10^{16}/cm^3$ - 1×10^{19} $/cm^3$. Also, it is preferred that the electron carrier concentration can be adjusted by doping the n type dopant such as Si, Ge, Sn and C on the 2nd n type layer. If the electron carrier concentration of the 2nd n type layer 33 is smaller than $1 \times 10^{18}/cm^3$, it is difficult to obtain the action of widening the electrons, a uniform active layer for emitting light is difficult to obtain. When it is larger than 1×10^{22} $/cm^3$, poor crystallinity is obtained. If the electron carrier concentration of the 1st n type layer is smaller than $1 \times 10^{16}/cm^3$, it is difficult to emit light from the active layer itself. Also, if the electron carrier concentration is smaller than $1 \times 10^{19}/cm^3$ and the film thickness is above 1 μm, the crystallinity tends to become poor, the output of the element is reduced.

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[0016] The thickness of the 2nd n type layer 33 is usually at a thickness of 10 angstroms to 1 μm. In addition, it is preferred to be formed at a thickness of 50 angstroms - 0.3

μm. If it is less than 10 angstroms, the crystallinity is insufficient, the action to enlarge the electrons is difficult to obtain and it is difficult to obtain light emitting from the uniform active layer. Also, since the cystallinity is poor as the thickness is more than 1 μm, the crystal flaw is generated easily in the 2nd n type layer, the function of the light emitting element becomes poor.

[0017] In addition, the 2nd n type layer 33 is preferred to be multilayered of above 2 layers of the gallium nitride type compound semiconductor with different composition ratio of In, Ga and Al. When this is a multilayered structure, it is preferred that the thickness of each layer is 10 angstroms - 1 μm. In addition, it is preferred that the thickness of the multilayered structure is at 50 angstroms - 0.3 μm. By multilayering this 2nd n type layer 33, the crystal flaw of the 1st n type layer can be suppressed with this multilayer film. Also, the torsion in the crystal can be buffered by the laminating of the gallium nitride type compound semiconductor. An excellent semiconductor layer having good crystallinity can be grown and the output of the light emitting element can be improved.

[0018] Next, figure 5 is the typical cross section showing the structure of the light generating element of another example of the invention. The 2^{nd} n type layer 33 is formed between the substrate 1 and the negative electrode 8 formed on the 1^{st} n type layer 3. This shows the distance of the 2^{nd} n type layer 33 and the negative electrode 8 is close. In this case, the electrode 8 can be formed on the surface of the 2^{nd} n type layer 33 with large carrier concentration. For example, as compared to figure 4, since there are a large concentration of electron carriers flowing through the 2^{nd} n type layer 33, Vf of the light emitting element can be reduced. In addition, when an insulated substrate is used such as sapphire, since the etching is difficult in terms of production technique with the stopping by the 2^{nd} n type layer 33, the distance of the 2^{nd} n type layer 33 and the negative electrode 8 shown in figure 5 is reduced. By having a large electron carrier concentration entering from the electrode 8 via the 2^{nd} n type layer 33, Vf can be reduced.

[0019] In addition, the substrate is made of sapphire, the n type layer, an active layer and a p type layer are laminated in this order on the surface of that sapphire substrate. In this light emitting element where an electrode is formed on the surface of the n type layer that

is etched and exposed with that p type layer and the active layer, the 2nd n type layer 33 is formed between the n type layer electrode formation surface and the substrate, the Vf can be reduced effectively. In addition, the light emitting element of the structure formed with the gallium nitride type compound semiconductor is grown on the surface of the conductive substrate such as SiC, ZnO and Si. The n type layer electrode is formed on the substrate side. The electrons at the n layer side is supplied to perpendicular to the active layer side. The electrons having the sapphire substrate as discussed above are supplied parallel to the active layer. The electrons that are supplied perpendicularly have a moving distance in the n type layer of several μm and the moving distance of the electron supplied in the parallel direction of several +μm to several hundred μm. Therefore, in the element where the electrons are supplied in the parallel direction, the carrier concentration of the 2nd n type layer supplying the electrons in the parallel direction is increased. The electrons move easily and the Vf is reduced.

[0020]

[Implementation example]

[Implementation example 1] According to the MOVPE method, the buffer layer 2 made from GaN is grown into a thickness of 0.02 μm on the top surface of the substrate 1 made from sapphire of 2 inch diameter. The 1st n type layer is formed on the top surface of this buffer layer 2. The n type contact layer 3 made with the n type GaN of 1 μm in thickness and of electron carrier concentration of $5x10^{18}/cm^3$ that is doped with Si is grown as the 1st n type layer on the surface of this buffer layer 2.

[0021] Next, the n type In0.1 Ga0.9N of 0.05 μm in thickness and of electron carrier concentration of $1x10^{20}/cm^3$ that is doped with Si is grown as the 2nd n type layer on the surface of the n type contact layer 3.

[0022] Next, the n type contact layer 3' made from GaN of 3 μm in thickness and of electron carrier concentration of $5x10^{18}/cm^3$ that is doped with Si is grown.

[0023] The n type clad layer made from the n type Al0.2Ga0.8N of 0.1 μm in thickness and of electron carrier concentration of $1x10^{18}/cm^3$ that is doped with Si is grown on the surface of the n type contact layer 3'. An active layer made from Si and Zn dope n type In 0.1Ga0.9N of 0.1 μm in thickness, the p type clad layer 6 made from Mg dope A 10.2Ga 0.8N and the p type contact layer 7 made from Mg

dope GaN are grown and laminated in this order on the top surface.

[0024] The wafer obtained according to the above method is introduced into annealing machine and it is annealed at 700 degree C. After the p type clad layer 6 and the p type contact layer 7 are made into a low resistance p type. The mask in a certain form is formed on the surface of the p type contact layer 7. Etching is performed from the p type contact layer side and the n type contact layer 3' is exposed.

[0025] Then, according to a normal method, after the positive electrode 9 is formed on the p type contact layer 7 and the negative electrode 8 is formed on the exposed n type contact layer 3', it is separated into a chip shape. This becomes the blue color light emitting element of the structure shown in figure 5. With this light emitting element, a uniform light emitting surface is observed, the main light emitting wavelength of 450 nm is from the active layer 5. In the current flow direction (If) is 20 mA, the Vf is 3.3V, the light emitting output is 1.8 mW.

[0026] [Implementation example 2] An n type contact layer 3 is grown into a thickness of 1 μm, this is made up of Ge doped GaN 10.1 of electron carrier concentration of 1 x $10^{18}/cm^3$, this is formed on the top surface of the buffer

layer 2. Next, the 2nd n type layer made from Ge dope In 0.2 Ga0.8N of 0.01 μm of electron carrier concentration of $5x10^{20}/cm^3$ is formed on this top surface. Next, the n type contact layer 3' made from Ge dope n type GaN of 2 μm of electron carrier concentration of $1x10^{18}/cm^3$, the 2nd n type layer 33' made from Ge dope n type In0.2Ga0.8N of 0.01 μm of electron carrier concentration of $5x10^{20}/cm^3$,Ge dope n type GaN layer of 1 μm of electron carrier concentration of $1x10^{18}/cm^3$ are formed in this order on the top surface of the 2nd n type layer 33.

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[0027] The n-type clad layer 4, the active layer 5, the p type clad layer 6, the p type contact layer 7 are laminated similar to that implementation example 1. This becomes the blue color light emitting element having the structure shown in figure 6. Therefore, as shown in figure 6, the depth of the etching is from the p type contact layer 7 to the n type contact layer 3'. The negative electrode 8 is formed on the surface of the n type contact layer 3'. Then, when this light emitting element emits light, a uniform surface light emitting is measured from the active

layer 5 similar to implementation example 1. The emitting output is 2.0 mW with Vf of 3.2 V and If of 20 mA.

[0028] [Implementation example 3] An n type contact 3 is grown into a thickness of 3 μm, this is made up of Si doped A 10.1 Ga0.9N of electron carrier concentration of 1 x $10^{18}/cm^3$, this is formed on the top surface of the buffer layer 2. Next, 5 layers each of the following are laminated on this top surface, Si dope In 0.2 Ga0.8N of 0.01 μm of electron carrier concentration of $1x10^{20}/cm^3$ and Si dope A 10.05 Ga0.95N of 0.01 μm of electron carrier concentration of $1x10^{20}/cm^3$. The 2nd n type layer 33 is grown.

[0029] Next, the following are formed and laminated in this order on the top surface of the 2nd n type layer 33, 0.1 μm of the active layer 5 made from Si and Zn dope n type In 0.1 Ga0.9N, the p type clad layer 6 made from the Mg dope A 10.2 GA0.8N and the p type contact layer 7 made from Mg dope GaN. Next, the active layer 5, the p type clad layer 6, the p type contact layer 7 are formed similarly without forming the n type clad layer 4 of implementation example 1. Then, the etching is performed similar to implementation example 1. The light emitting element having the structure shown in figure 3 is obtained. Uniform surface light emitting is obtained from the active layer 5 similar to

when this light emitting element emits light. When If is 20 mA, Vf is 3.5 V, the light emitting output is 2.2 mW.

[0030] [Comparison example] The 2nd n type layer 33 in implementation example 1 is not formed here but the rest of the example is carried out similarly. A GaN contact layer is formed continuously to 4 μm thickness. The structure of this light emitting element is shown in figure 1. The active layer of this light emitting element has strong light emission between the positive electrode 9 and negative electrode 8 shown in figure 2. A uniform light emission cannot be obtained. Also, when If is 20 mA, Vf is 3.6 V, the light emitting output is 1.2 mW.

[0031]

[Effect of invention] According to the invention as described above, this light emitting element can provide improved light emitting output, a uniform light emitting surface can be obtained from the whole active layer. Also, according to implementation examples 1 and 2, the 2nd n type layer 33 is formed between the negative electrode 8 and the substrate 1, it is clear the Vf is reduced. Also, in implementation example 3, since the 2nd n type layer is not formed between the substrate and the negative electrode, the reduction of Vf is not affected. Also, since the 2nd n type layer is multilayered, there are less flaws in the

crystal in the active layer, the p type clad layer and the p type contact layer. The light emitting element of the invention can be formed at the active layer side where the 2^{nd} n type layer is bonded to the 1^{st} n type layer. Uniform light emitting surface can be obtained. Thus, the element with improved light emitting output can realized.

[Brief explanation of the diagrams]

[Figure 1] This is a typical cross section showing the structure of the conventional light emitting element.

[Figure 2] This is a typical cross section showing the light emitting state of the light emitting element of figure 1.

[Figure 3] This is a typical cross section showing the structure of the light emitting element of one implementation example of the invention.

[Figure 4]] This is a typical cross section showing the light emitting state of the light emitting element of figure 3.

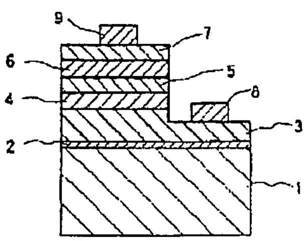
[Figure 5] This is a typical cross section showing the light emitting state of the light emitting element of another implementation example of the invention.

[Figure 6] This is a typical cross section showing the light emitting state of the light emitting element of another implementation example of the invention.

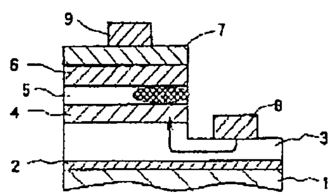
[Description of the symbols]

1 - the substrate, 2 - the buffer layer, 4 - the n type clad layer, 5 - the active layer, 6 - the p type clad layer, 7 - the p type contact layer, 8 - the negative electrode, 9 - the positive electrode, 3,3′,3″ - The 1st n type layer (n type contact layer), 33, 33′ - The 2nd n type layer

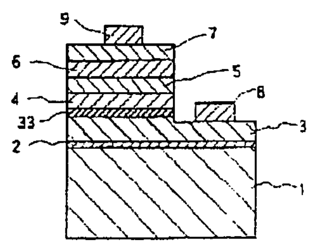
【図1】



【図2】

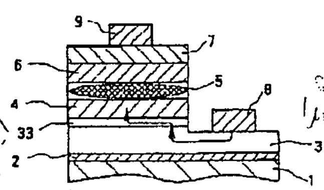


【図3】

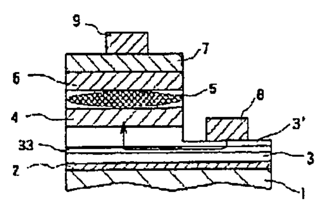


InGaN

【図4】



【図5】



AlGaN clad

【図6】